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THERMAL DISCHARGES

Behavior Of Thermal Discharges

Before judgments can be made about the impacts of thermal discharges, data must be available on how thermal plumes behave in the aquatic environment. TVA's Division of Water Management is developing computer models for analyzing the effects of thermal discharges from steam plants on temperatures and velocities in a receiving body of water. These models numerically simulate boundary conditions in the particular body of water being modeled. The numerical models are of two broad classes. One class, a 2-dimensional, unsteady model encompasses an entire reservoir or a long reach of a river and predicts effects over a period of several months or for as long as a year. The second class of model is a 3-dimensional, unsteady model that offers relatively fine resolution within about 10 km of the plant for periods of several hours or days. Figures 1 and 2 are examples of results produced by these two models.

Effects Of Thermal Discharge

Since 1973 TVA has been actively investigating the effects of thermal discharges on the aquatic communities in bodies of water receiving heated water from its steam plants. Section 316(a) of the Federal Water Pollution Control Act Amendments of 1972 allows dischargers of waste heat to demonstrate that impacts from specific plants do not harm aquatic environments receiving the thermal effluents. TVA established a program

in accordance with Section 316(a) to assess the impact of thermal effluent from eight of TVA's fossil-fueled steam plants. Most of these eight plants are on multipurpose, flow-through reservoirs; the aquatic habitats near the plants are neither entirely lacustrine nor riverine but involve environments that at times resemble one or the other. The TVA 316 studies were divided into two approaches: the nonfisheries aspect and the fisheries aspect. In addition, a special project has been implemented to assess long-term, sublethal thermal effects.

Nonfisheries

In evaluating the impact of thermal discharge from fossil-fueled power plants, TVA's biologists have found that the effects of these discharges are generally inconsistent with regard to temperature difference, ambient temperatures, power production, etc. No definitive correlations of cause and effect have been determined from the data for any nonfisheries community. The impacts seem to be intermittent types of responses (i.e., one study period may exhibit an effect in a community and the next nine study periods may not). The inconsistency of these responses suggests that the nonfisheries communities are not altered on a long-term basis by the thermal discharge.

Phytoplankton--This community consists of microscopic unicellular and multicellular nonvascular plants passively supported in the water column. The thermal effect studies for this community have shown that, in general, there are no significant differences between control and experimental stations. When an effect is observed, it usually occurs as an alteration in cell densities. At one plant during 16 study periods, no significant differences in population between control and

experimental stations were determined for 14 study periods. In one of the remaining two periods, the cell densities decreased 52 percent downstream. In the other period the densities increased 1,048 percent.

Periphyton--Periphyton are microscopic plants and animals that attach to, but do not penetrate into, a submerged substrate. The most frequent responses of the sessile algal community (phytoperiphyton), when changes were found, were reductions or increases in the biomass of the community. Thermophilic "nuisance" algae such as blue-green algae dominated the community in less than five percent of the cases studied.

Aquatic Macrophytes--Aquatic macrophytes are the rooted and floating vascular plants. No significant response by aquatic vascular plants to thermal discharges was identified.

Zooplankton--Zooplankton are microscopic animals suspended in the water column that are capable of swimming short distances or avoiding weak currents. Reductions in total numbers and in total biomass and shifts in dominant taxa were documented occasionally at some of the study sites. However, these effects were encountered infrequently and would not be interpreted to pose a problem to the environment when considered along with other data.

Additional studies were conducted in 1974 and 1975 to determine the percentage of the zooplankton killed by passage through the condenser cooling system. Although all samples have not yet been processed, these studies indicate the percentages of mortality to be low except at plants where chloride is used as a biocide or where there is a great rise in temperature as water passes through the cooling system. Effects at these plants are similar to those reported in the literature.

Benthos--Benthos is a generic term for all organisms that are attached to, resting on, or living in the bottom sediments of a body of water. This assemblage is comprised of such organisms as aquatic insects, aquatic worms, freshwater mussels, clams and snails. In cases in which an effect was observed in this community, it was manifested by a decrease in diversity. Modified drift studies showed that suspension in the thermal plume did not significantly alter body functions of mayfly and damselfly larvae.

Fisheries

Fisheries studies were conducted in the vicinity of these eight TVA plants during 1974-1975. Results indicate that some species avoid plant discharge areas during warmest periods of the summer and that others are attracted to discharge areas during winter. There is no change in the distribution of species, however. In addition, there are typically no changes in growth, condition, parasite loads, gonadal maturation, and spawning times in fish exposed to thermal discharges. No barriers to spawning migration have been found at TVA plants, nor has there been any documented fish kill resulting from cold shock because of power plant shutdown. Analyses of historical data (in some cases including preoperational data) have revealed no changes in reservoir fish populations that could be attributed to heated effluents.

Assessment of Long-Term Thermal Effects

TVA, in cooperation with the Environmental Protection Agency, is also studying the long-term sublethal effects of thermal discharges on selected species of fish and associated aquatic flora and fauna.

A thermal research facility was completed in 1974 at Browns Ferry Nuclear Plant on Wheeler Reservoir in Alabama. Water is pumped through a series of 12 channels 114m x 4.3m x 2m (figure 3), each with identical substrate of natural reservoir sediments and limestone rocks (figure 4). Water temperature, dissolved oxygen, pH, and flow rate for each channel are monitored continuously. Water that is 2, 4, and 6^{o}C above ambient river temperature will flow through three sets of three channels and river water at ambient temperature will flow through one set of three channels (which will serve as experimental controls).

Preliminary experiments have been conducted since 1974 under ambient river temperatures to produce baseline data on rates of natural colonization of periphyton, macroinvertebrates and plankton in the channels. Assessments were made on growth, survival, and reproduction of seven species of fish with emphasis on smallmouth bass, bluegill, sauger, and walleye. Experiments at elevated temperatures will begin in Spring, 1977.

USE AND MANAGEMENT

TVA is actively engaged in research in each of three approaches to the problem of using or managing waste heat. The first approach is to use more of the heat in the production of electricity (i.e., increase the efficiency of power generation). The second approach is to use the rejected heat for some beneficial purpose other than the production of electricity. The remaining option is to manage the waste heat so that it will have minimum adverse impact on the environment.

Improved Power Plant Efficiency

A highly desirable solution to the problem of waste heat would be to utilize more of the heat to generate electrical power and thereby reduce the discharge of waste heat. TVA, either directly or through participation with other organizations, is involved in research into technologies such as high-temperature gas turbines, fuel cells, and magnetohydrodynamic generators, which hold promise for improving power plant efficiencies as much as 50 percent. For many years to come, however, 50 to 60 percent of the heat produced by fuels will be wasted and will require disposal or will be available for beneficial use.

Beneficial Use Of Waste Heat

Another desirable approach to dealing with waste heat is to find a beneficial use for it. In 1969 TVA began its first research project in beneficial uses of waste heat--the intensive culture of

catfish in the thermal discharge from condenser cooling at Gallatin Steam Plant. In 1971 the Board of Directors of TVA approved a broad program for evaluating beneficial uses of waste heat. TVA's policy is to concentrate on the use of true waste heat--heated water as it leaves the power plant with no alterations to the overall thermal cycle. Several studies are in progress at TVA.

Raceway Catfish Production

TVA's first study of beneficial use of waste heat was a cooperative effort with a private corporation and involved the production of catfish in the heated-water discharges from Gallatin Steam Plant. The objectives of the study were to (1) determine the effects of stocking density and water flow on growth, feed conversion, and mortality of catfish; (2) develop effective control of disease in densely stocked catfish; (3) develop treatment for waste produced by a catfish culture; (4) test aeration and oxygenation systems; and (5) evaluate the environmental impact and economic feasibility of the system.

The project was judged technically feasible and was concluded in 1974. Economic feasibility is yet undetermined. Results, however, indicate a significant potential for commercial success of high-density culture of catfish at power plants.

TVA is involved in a multiagency proposal for research in aquaculture that could lead to the design and construction of a larger scale demonstration of catfish production at a TVA power plant. The Gallatin project forms a basis for this expanded effort.

Greenhouse Heating and Cooling

Heat energy in water that has been used for cooling condensers can be used to heat or cool greenhouses. A prototype greenhouse, which uses simulated waste heat, has been in operation at Muscle Shoals, Alabama, for several years and has provided engineering, horticultural, and economic data. A waste heat research facility at TVA's Browns Ferry Nuclear Plant, scheduled for completion in late 1977, will be used for further evaluation of the technology developed with the prototype greenhouse. Figure 5 shows the design of the planned experimental greenhouse at Browns Ferry. Research continues at the prototype facility to document horticultural, engineering, and economic data for different crops and to make comparisons with data from conventional greenhouses.

Biological Recycling of Livestock Wastes

Research is in progress at the National Fertilizer Development Center, Muscle Shoals, Alabama, to evaluate the use of waste heat in managing livestock manure and producing useful byproducts. Recycling systems will also help a livestock enterprise to function with minimum environmental impact. This project will principally investigate the feasibility of using heated water to grow aquatic plants to remove nutrients from animal wastes. Another part of the system is being operated to determine the usefulness of the aquatic plants as a primary source of food for such aquatic animals as fish, freshwater mussels, and other aquatic animals that may then be harvested and used as a high-protein supplement for livestock rations and possibly even for human consumption (figure 6). The aquatic animals being produced in the recycling system are sent to Auburn University for evaluation as a high-protein supplement for livestock rations.

Soil Heating

Field test plots are being used to evaluate the use of waste heat from power plants for producing agricultural and horticultural crops. Results to date indicate that heating of soil can double the yields of some vegetable crops. Figure 7 shows an example of the difference between plants grown in heated soil compared to plants grown in unheated soil. Research at Muscle Shoals involves the use of a soil heating system to determine responses of crops to varying water temperatures and methods of heat application to simulate the diverse systems of power plants expected for the TVA system of the future. A prototype greenhouse was erected in 1976 over soil warmed by heated water (figure 8). Additional research is planned that will identify the optimum water temperature for maximum plant growth during spring and fall. Investigations are also planned to determine the maximum water temperatures that can be tolerated in midsummer without a reduction in plant growth.

Temperature Control for Livestock Facilities

Previous research indicates that livestock convert feed to body weight more efficiently when the temperature of the environment is controlled. With swine, maximum efficiency of feed conversion takes place at a constant temperature of about 60°F, and comparable results are expected with other livestock. Waste heat research in temperature control, already completed in the greenhouse experiments, will be useful in developing an environmental control system for confined livestock. The system has the potential for reducing the total amount of grain needed to bring livestock to a marketable size. The literature is being

reviewed during 1977. If the review shows justification for design and construction of a pilot-scale, temperature-controlled facility for livestock production, using waste heat, it will be planned for 1978.

Because the economics of waste heat utilization are, at present, dwarfed by the economics of power production, care must be taken to ensure that appropriate consideration is given to both objectives. For example, at TVA's Hartsville Nuclear Plant, special connections will be provided on both the hot water and cold water conduits of the heat rejection system so that waste heat may be provided at optimum temperature and cost. Waste heat utilization processes must not, however, interfere with efficient and environmentally acceptable dissipation of waste heat and must not create conditions that would adversely affect the economic generation of power.

Heat Rejection Technologies

The remaining option for the control of waste heat is to manage the thermal discharge so that costs and environmental impacts are minimized. TVA conducts research to advance the state of the art in heat rejection technology and to determine the environmental impacts of these technologies.

Because the selection and sizing of a heat rejection system has a great impact on the economics of generation of electrical power, it is important to choose the optimum combination of design parameters. Computer optimization programs have facilitated this search for optimum combinations and have pointed out combinations involving a broad spectrum of heat dissipation devices.

Within TVA there are several research projects in progress to evaluate various heat rejection technologies.

TVA Spray Project

TVA is considering a project to determine its ability to design spray systems for either ultimate heat sink or condenser cooling. The project would use a full-scale test facility with an ultimate heat sink to provide data necessary for a comprehensive analysis of spray phenomena.

Wet/Dry Cooling Tower Project

TVA and EPA will jointly investigate new wet/dry cooling tower technology. The wet/dry cooling tower (figure 9) is an attractive alternative to all wet or all dry cooling towers because the wet/dry tower can operate for thermal performance, water conservation, and plume abatement. The project requires a full-scale wet/dry tower with necessary instrumentation and experienced personnel. Data will be gathered on thermal performance, water consumption, and plume abatement. These data will be used to accurately predict the performance of wet/dry cooling towers.

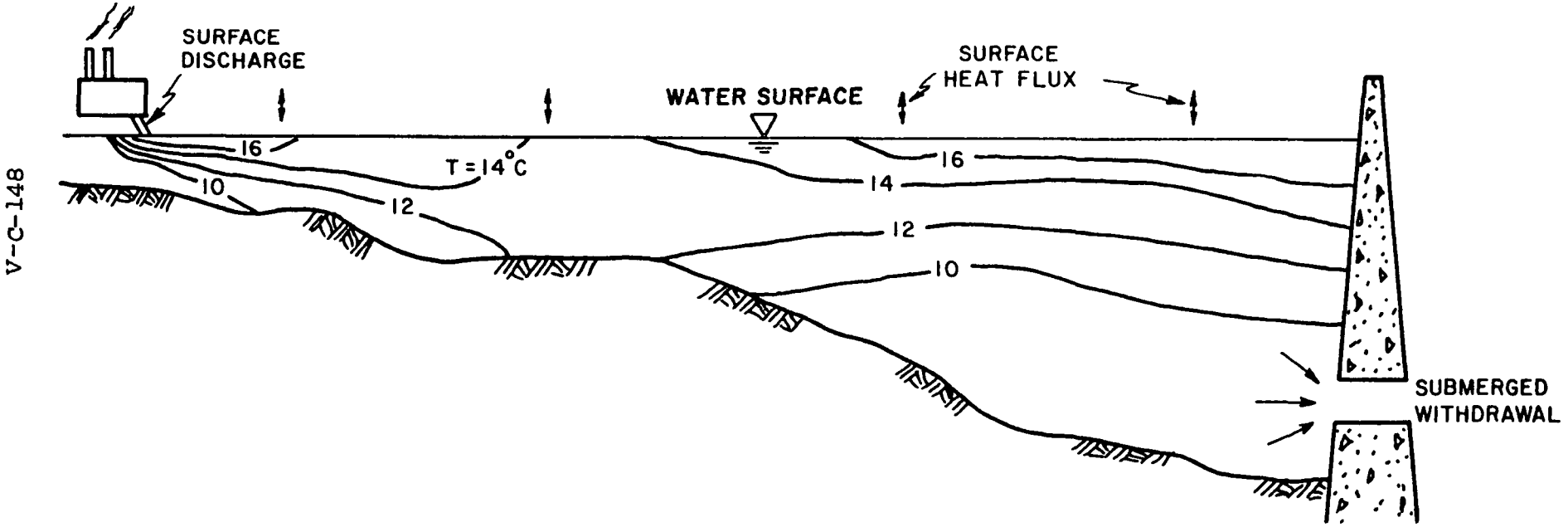
Prediction of Scale Formation

Recirculating evaporative cooling systems will be studied to enable TVA to predict the maximum concentrations of scale-producing material that can be present in cooling water without producing scale in cooling towers. The preliminary goal will be to identify the relationships that control CO_2 transfer from the cooling tower. A pilot cooling

tower will be used in this study. Data from utilities in the United States that use wet cooling towers will also be studied to determine factors that cause scaling. Results of the project will be used to predict the maximum concentration of scale-producing material that can be sustained in TVA's systems that use cooling towers. The pilot tower will be used at various locations to verify results.

CONCLUSION

Fossil-fueled and nuclear generating plants will be found with the problem of waste heat for some time to come. Methods of dealing with the problem must include considerations of the possible environmental impacts of thermal discharges and, where possible, considerations of useful applications of this waste heat in an energy-hungry society. Close cooperation between all applicable sciences will be important to the continuing development of new uses and controls for waste heat.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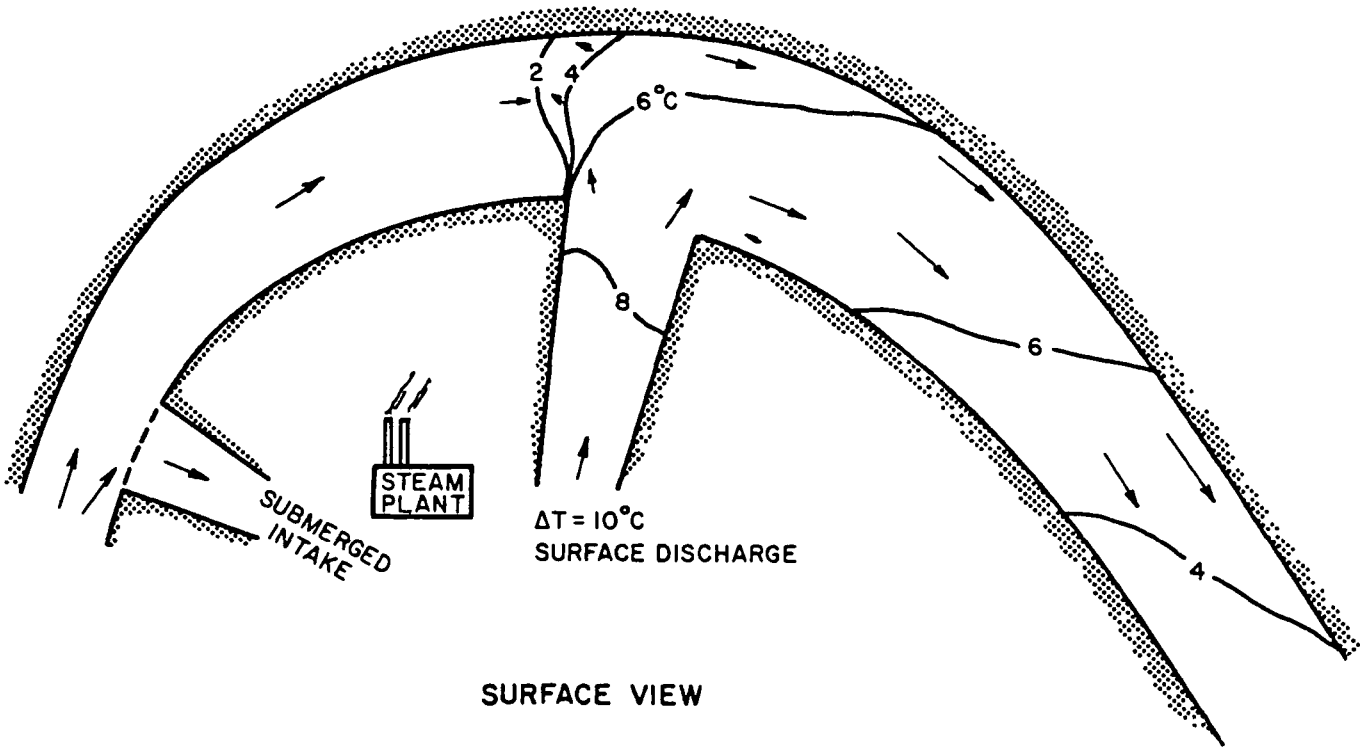

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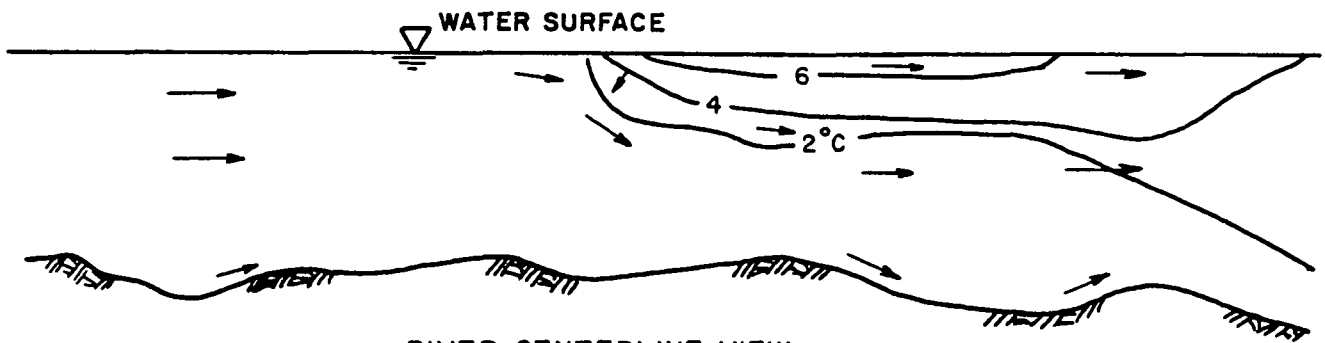
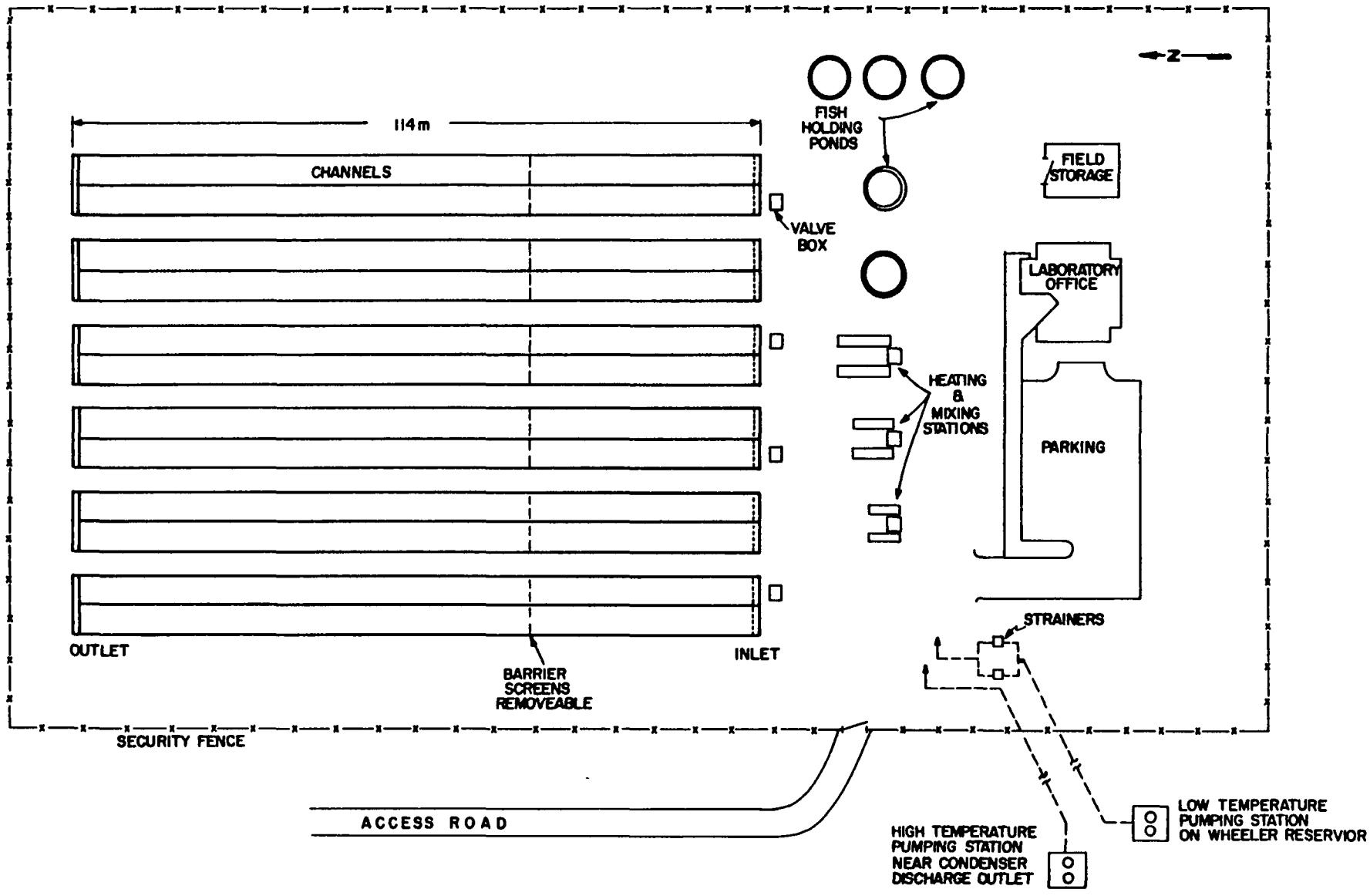
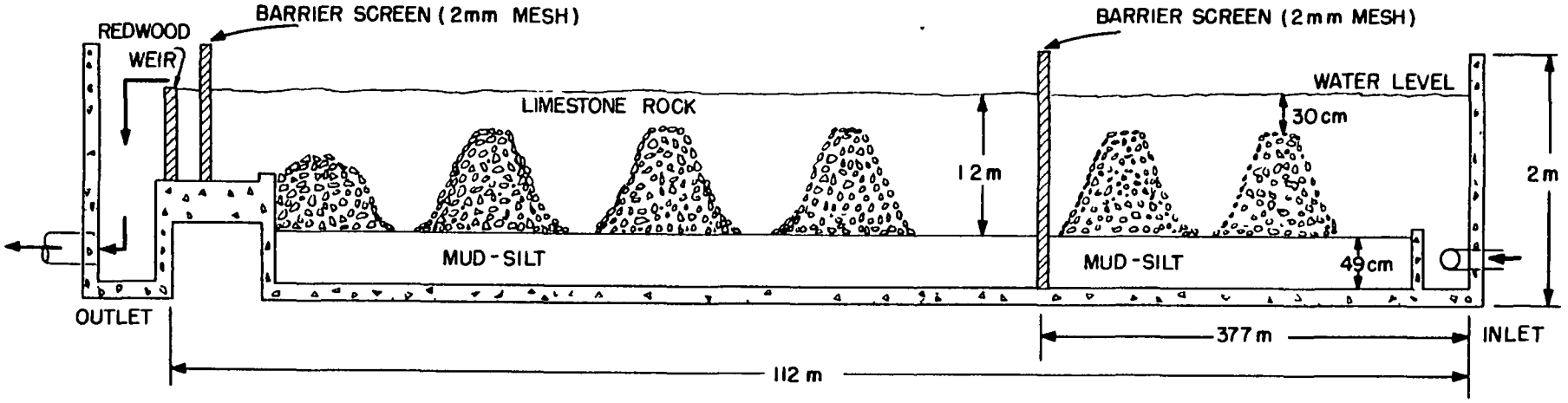


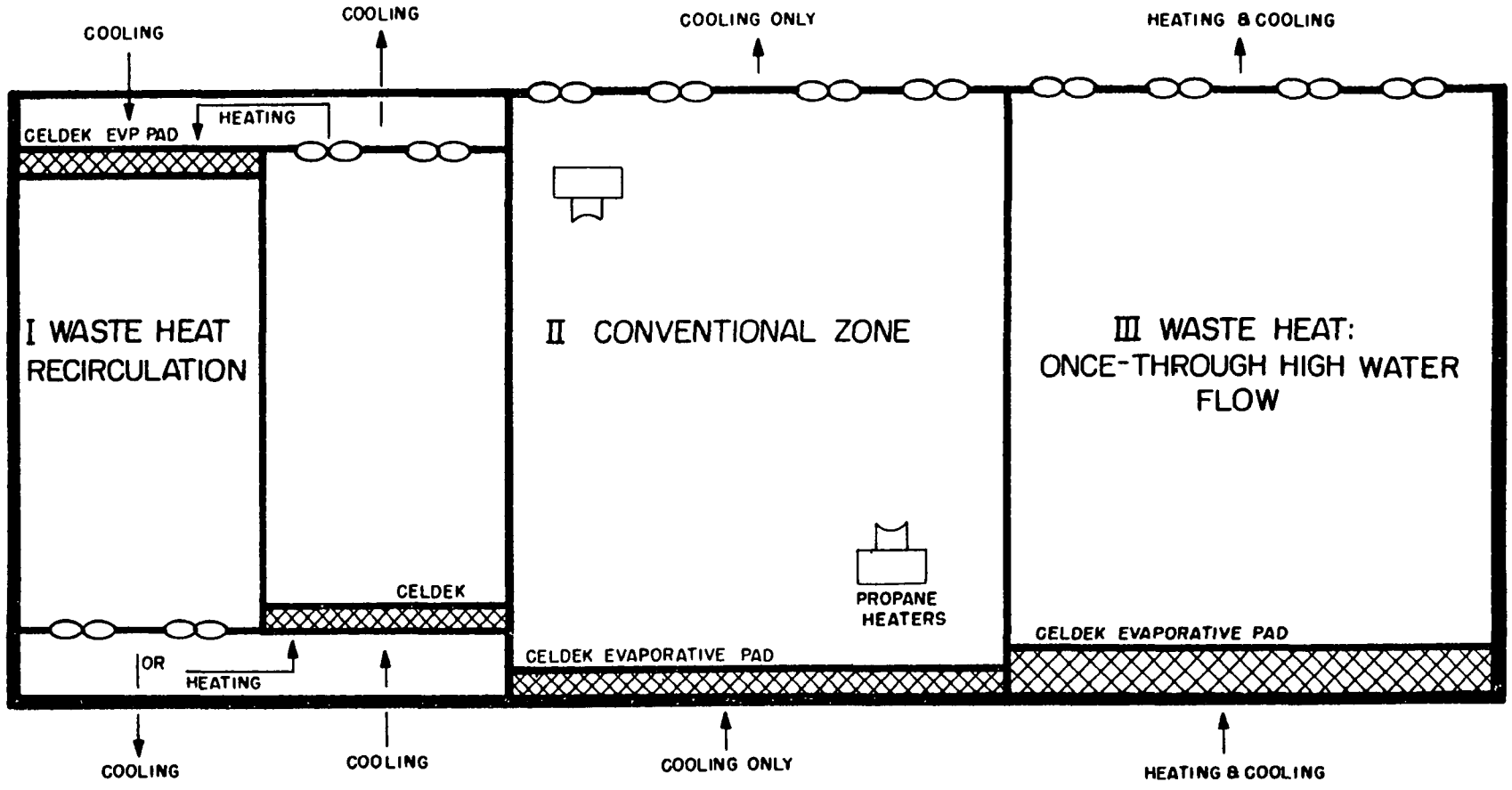
RIVER CENTERLINE VIEW



PLANVIEW OF EXPERIMENTAL CHANNELS AND AUXILIARY FACILITIES



PROFILE OF BROWNS FERRY EXPERIMENTAL CHANNEL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II CONVENTIONAL ZONE
III WASTE HEAT: ONCE-THROUGH HIGH WATER FLOW
CELDEK
PROPANE HEATERS
CELDEK EVAPORATIVE PAD
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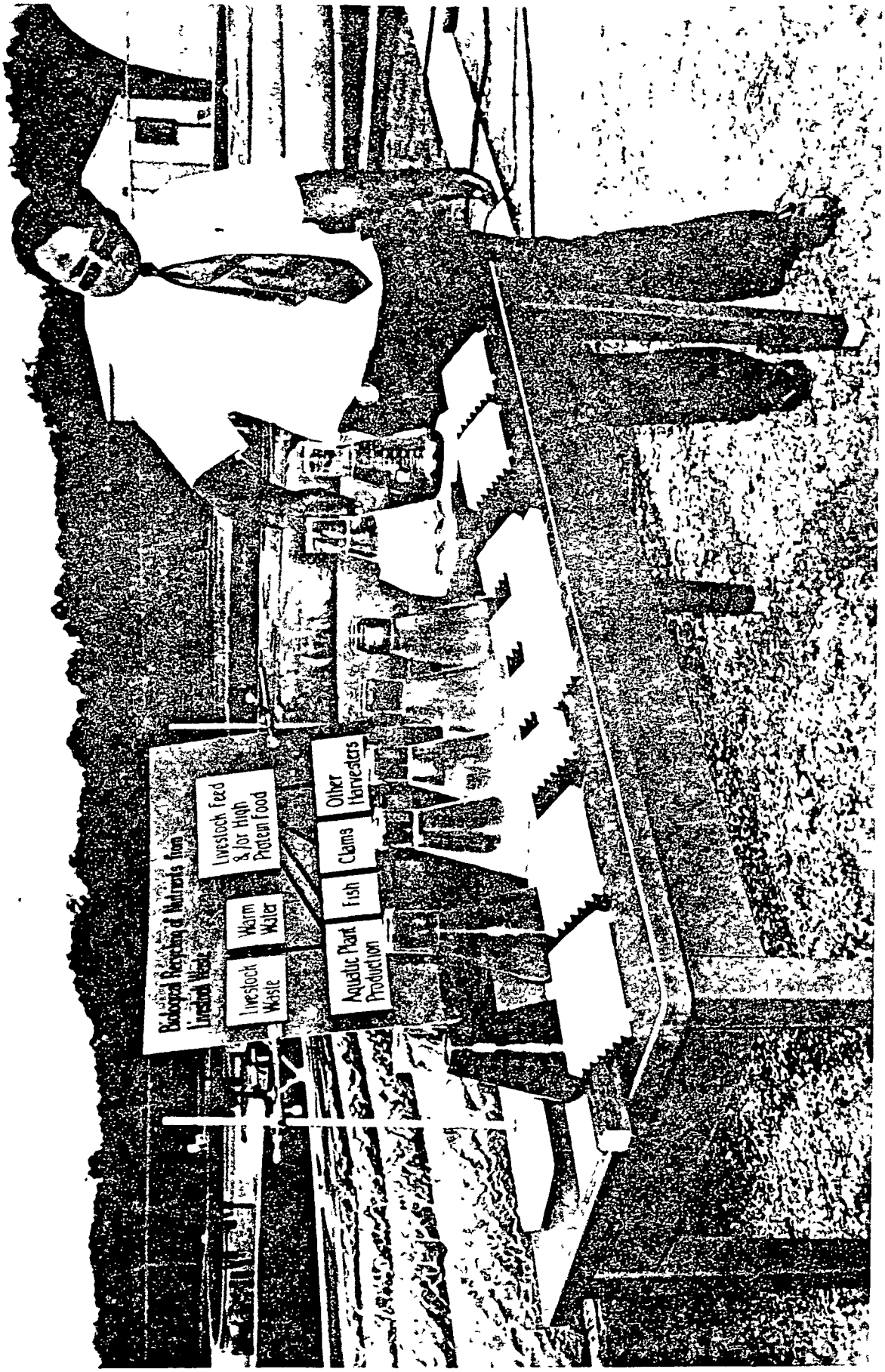
Biological Recycling of Nutrients from Limited Waste
Livestock Waste
Warm Water
Aquatic Plant Production
Fish
Clams
Other Harvesters
Livestock Feed &/or High Protein Food


70°F
NO
HEAT